

Global AMSR2 RFI Monitoring

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2015 STAR ICVS Instrument Performance Review

NOAA Center for Weather and Climate Prediction Conference Center

May 8, 2015

Outline

- **Motivation**
- **Double PCA for RFI Detection over Land**
 - ✓ Snow
 - ✓ Ice Sheet over Greenland and Antarctic
- **Observation-based TFI Detection over Ocean**
- **RFI Mitigation over Land by AMSR2 7.3 GHz**
- **Summary and Publications**

Motivation

- AMSR2, GMI, WindSat, AMSR-E and MWRI data are **contaminated** by radio frequency signals from active ground remote sensing systems and TV satellites
- If not detected and corrected, RFI/TFI signals cause **false strong precipitation** and **false low water vapor** over ocean and wet soil moisture over land
- **ATMS** band may also be weakly affected by RFI/TFI signals, which need to be detected and corrected by developing a set of elegant algorithms

AMSR2 Channel Characteristics

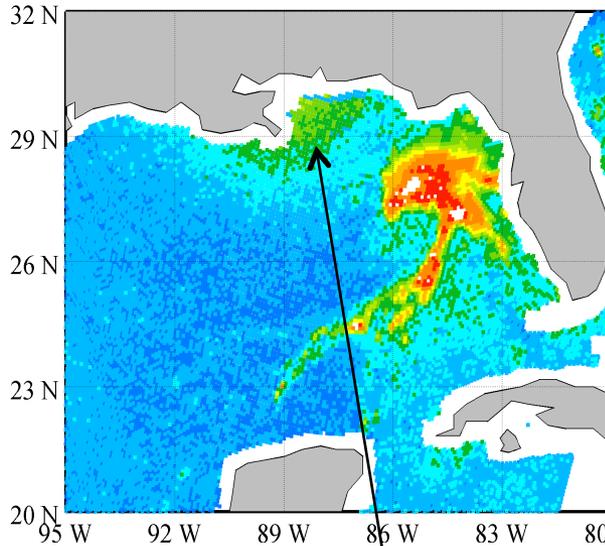
Channel Frequency [GHz]	NEDT [K]		IFOV [km ²]		Beamwidth [deg]	
	AMSR-E	AMSR2	AMSR-E	AMSR2	AMSR-E	AMSR2
6.925	0.34	0.34	74×43	62×35	2.2	1.8
7.3		0.43		58×34		1.8
10.65	0.7	0.7	51×30	42×24	1.4	1.2
18.7	0.7	0.7	37×16	22×14	0.8	0.65
23.8	0.6	0.6	31×18	26×15	0.9	0.75
36.5	0.7	0.7	14×8	12×7	0.4	0.35
89.0	1.2	1.2	6×4	5×3	0.18	0.15

Retrieval Product	Involved Channels [GHz]
Total Precipitable Water (TPW)	18.7, 23.8, and 36.5
Liquid Water Path (LWP), rain water path (RWP)	
Precipitation Rate	36.5, and 89.0
Sea Surface Temperature (SST)	6.925
Sea Surface Wind (SSW)	6.925, and 36.5
Sea Ice Concentration	18.7, 23.8, and 36.5
Snow Depth	10.65, 18.7, 36.5, and 89.0
Soil Moisture Content	10.65, 18.7, 36.5, and 89.0

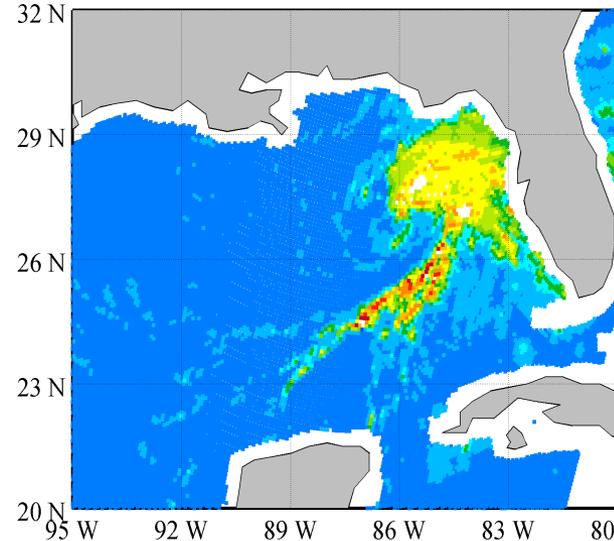
RWP Retrievals from Two AMSR2 Channels

TC Andrea at 0738 UTC June 6, 2013

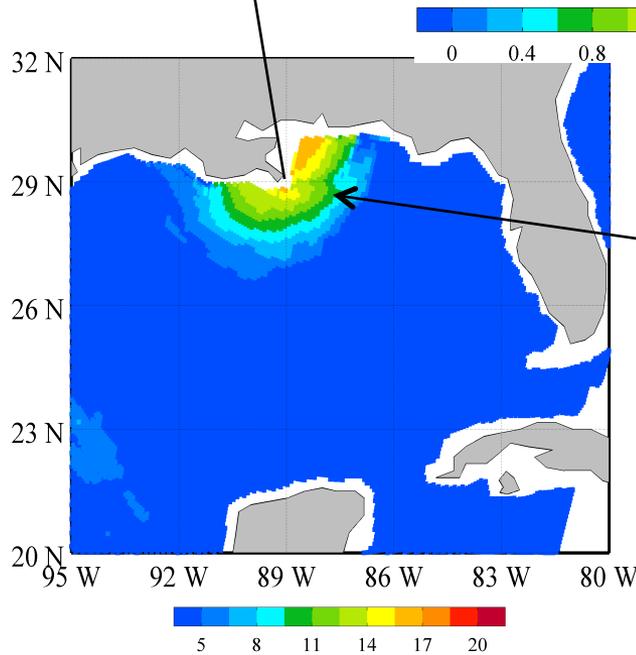
RWP
(18.7 GHz)



RWP
(36.5 GHz)



RFI at 18.7 GHz

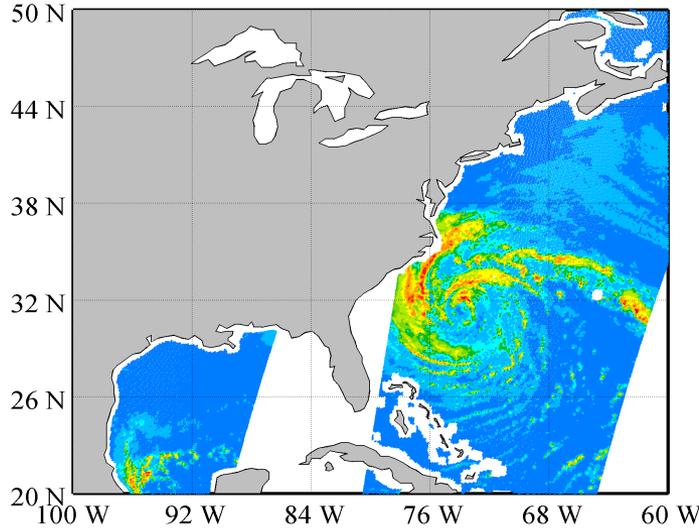


RFI signals at 18.7 GHz, if not removed, produce **false** RWP near a coastal area southwest of TC Andrea!

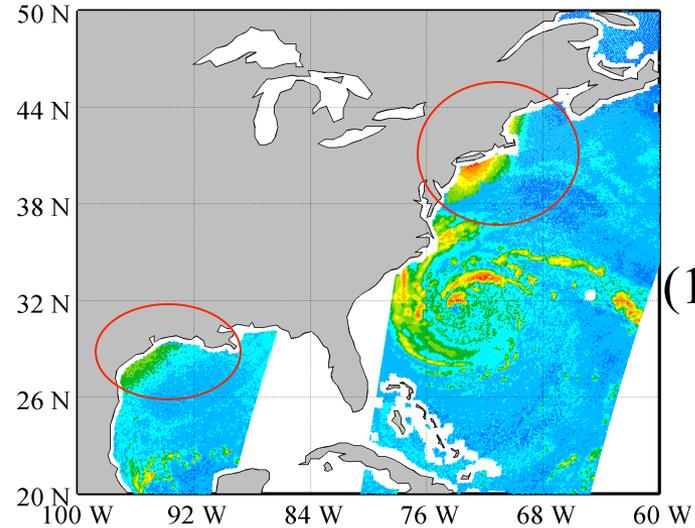
LWP Retrievals from Two AMSR2 Channels

Hurricane Sandy at 0629 UTC October 28, 2012

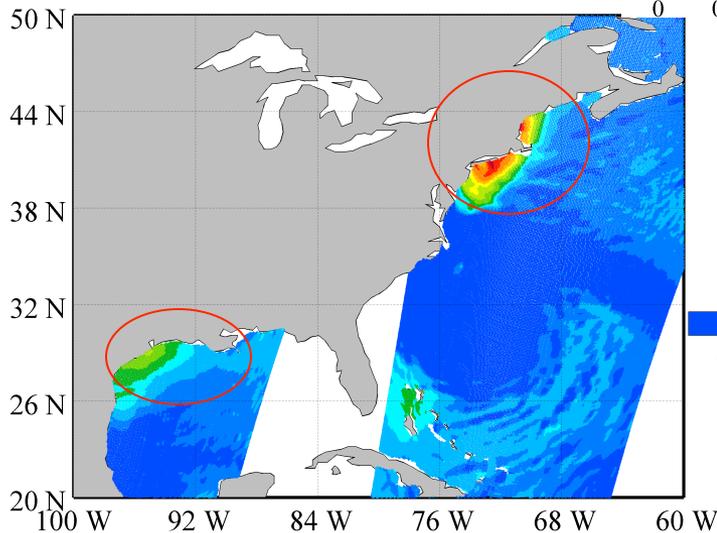
LWP
(36.5 GHz)



LWP
(18.7 GHz)



(kg m⁻²)
0 0.4 0.8 1.2 1.6 2



RFI at 18.7 GHz

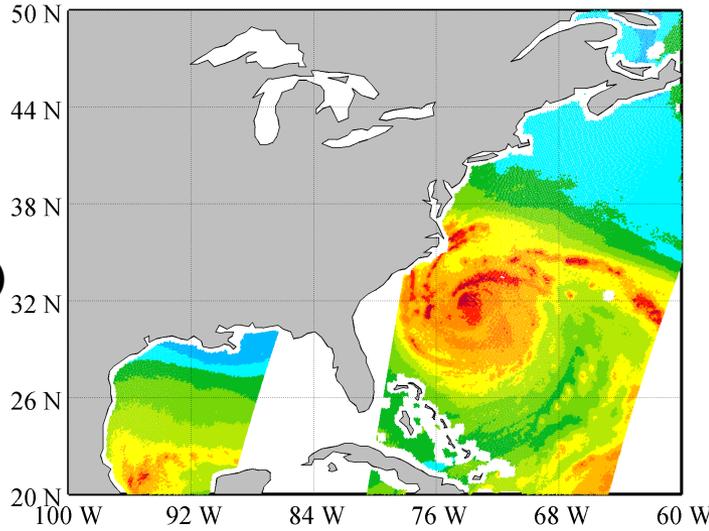
0 6 12 18 24 30

RFI signals, if not removed, produce false LWP near the coastal areas!

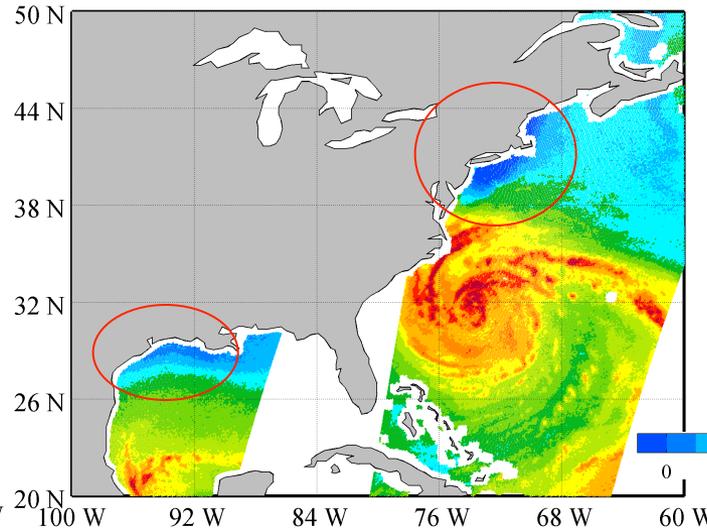
TWP Retrievals from Two AMSR2 Channels

Hurricane Sandy at 0629 UTC October 28, 2012

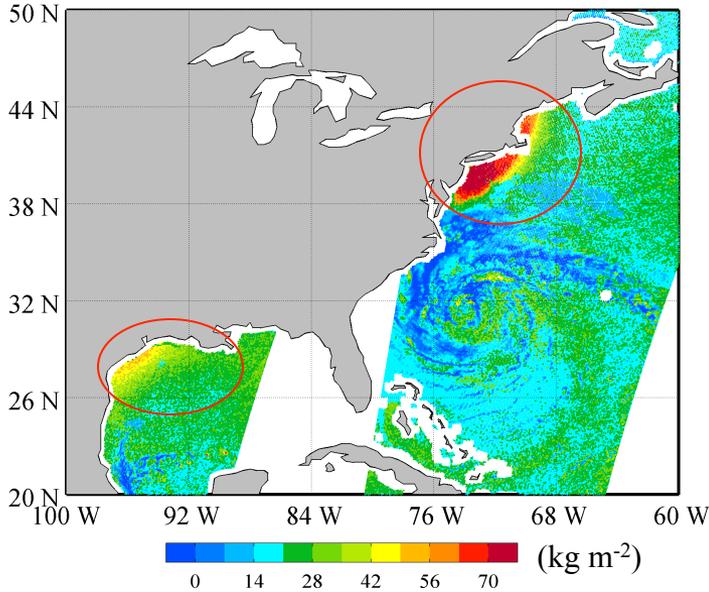
TPW
(36.5 GHz)



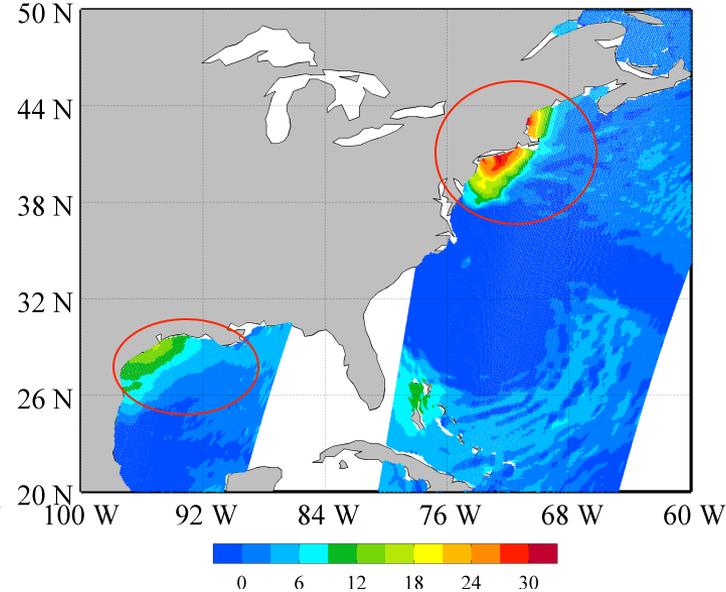
TPW
(18.7 GHz)



TPW_{36.5}
-TPW_{18.7}



RFI at
18.7 GHz



RFI signals, if not removed, **reduce** TPW values near the coastal areas!

Outline

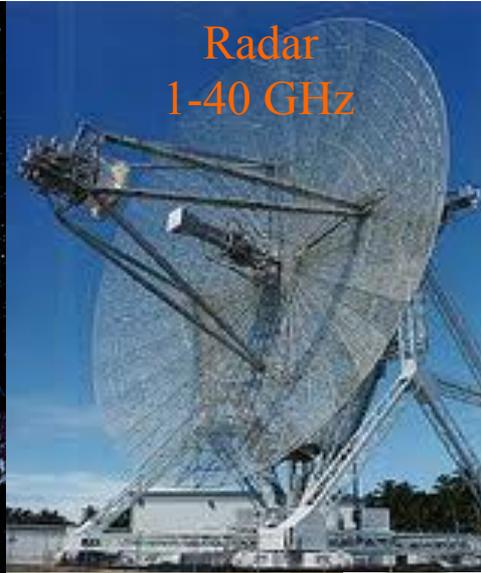
- Motivation
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Active remote sensing usually uses **low-frequency** channels.

(C-band: 4-8 GHz, X-band: 8-12 GHz, K-band: 18-26.5 GHz)



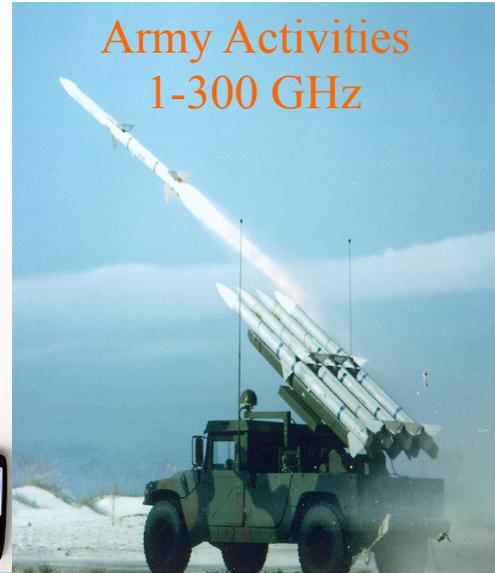
TV Satellite (Astra)
10.7-12.7 GHz



Radar
1-40 GHz



Cell Phone
0.7-3.0 GHz



Army Activities
1-300 GHz



Speed Monitor
8-40 GHz



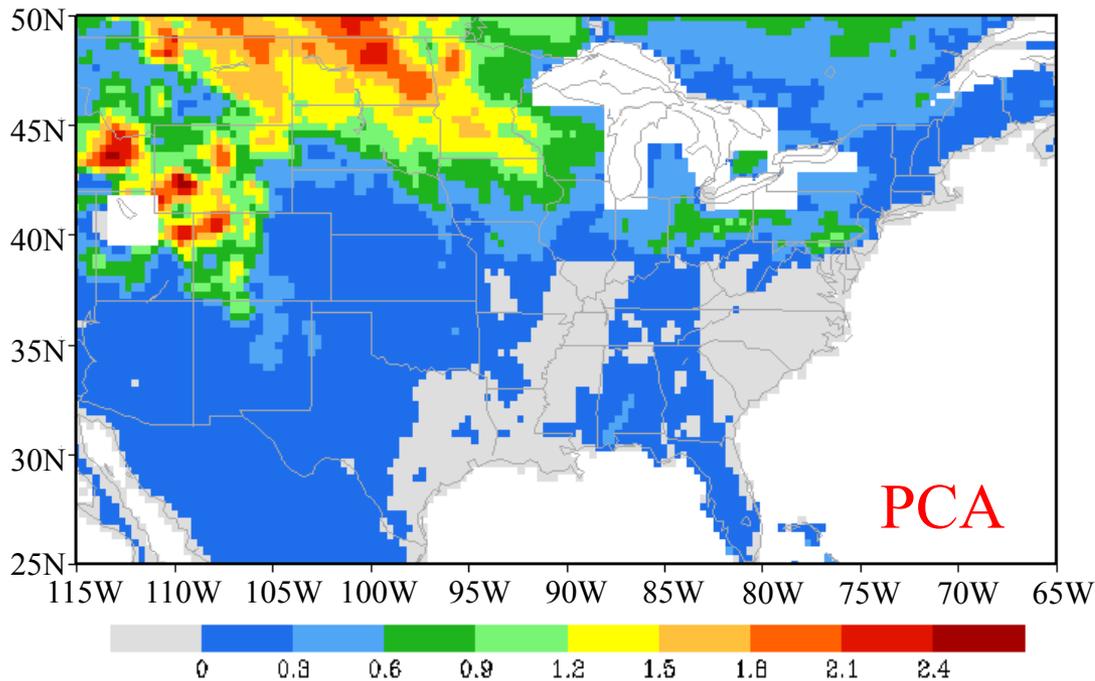
Garage Door Opener
0.3-0.4 GHz



Ship
0.1 GHz

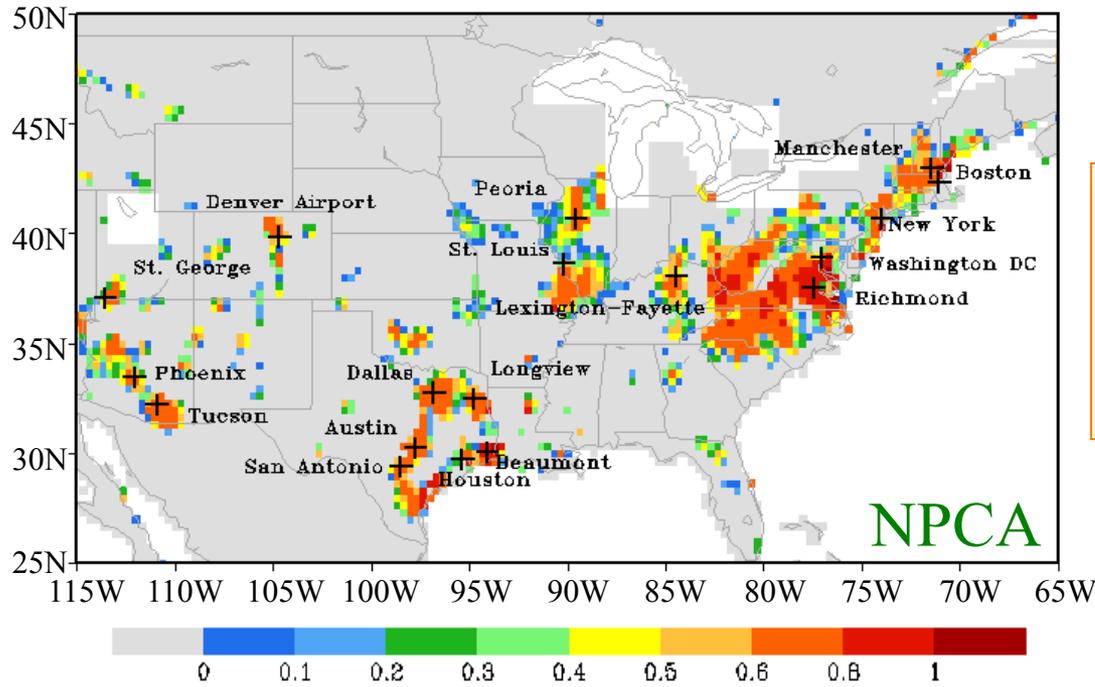


Airplane
0.1 GHz

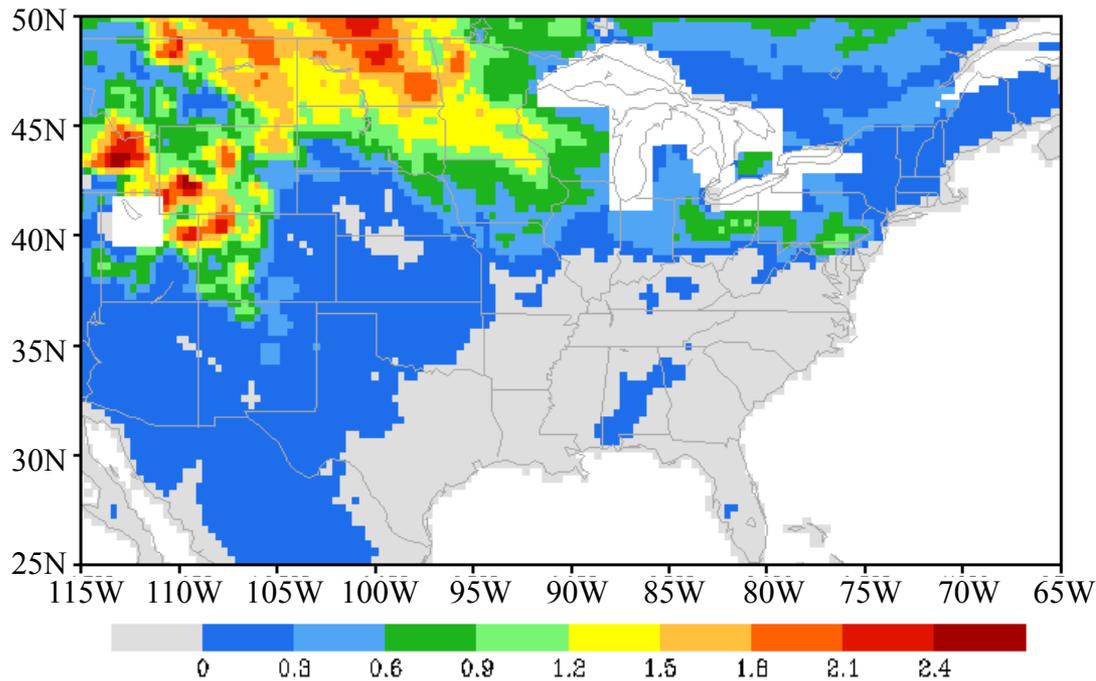


RFI at 6.8h

PCA doesn't work in the presence of snow.

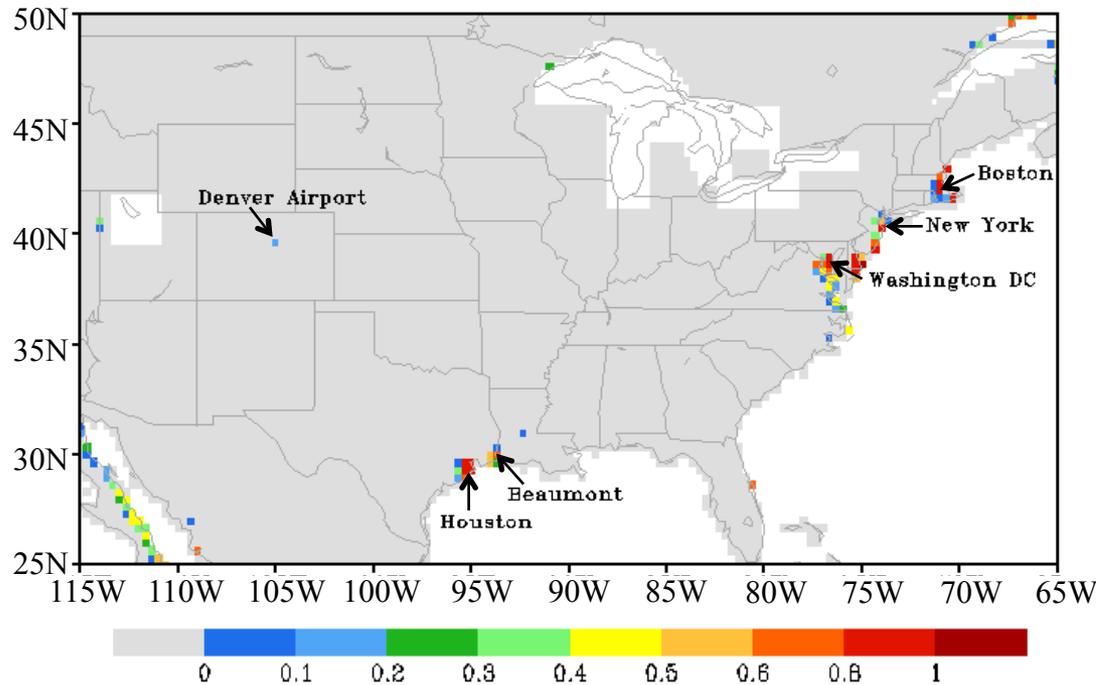


NPCA eliminates the false RFI signals due to snow while detected RFI signals in areas without snow.



RFI at 10.7h

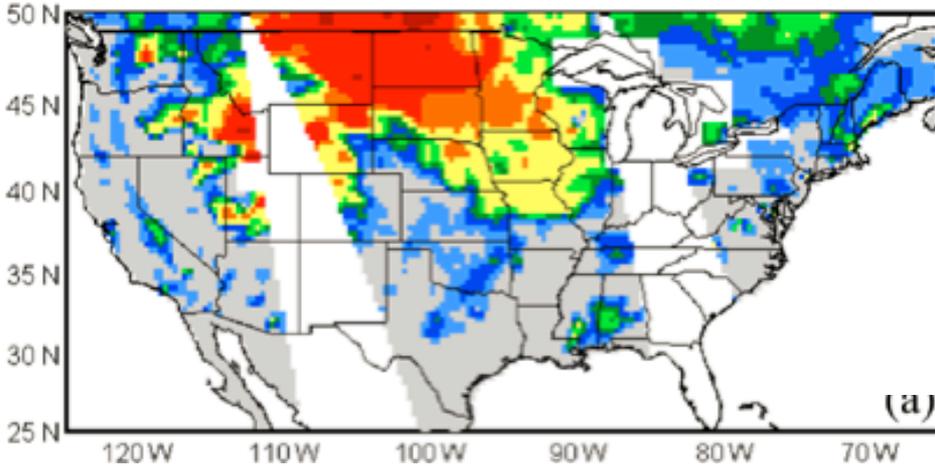
PCA doesn't work in the presence of snow.



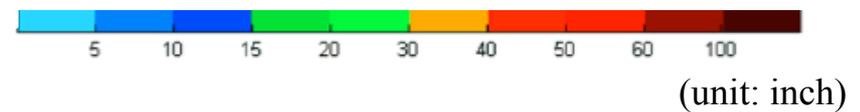
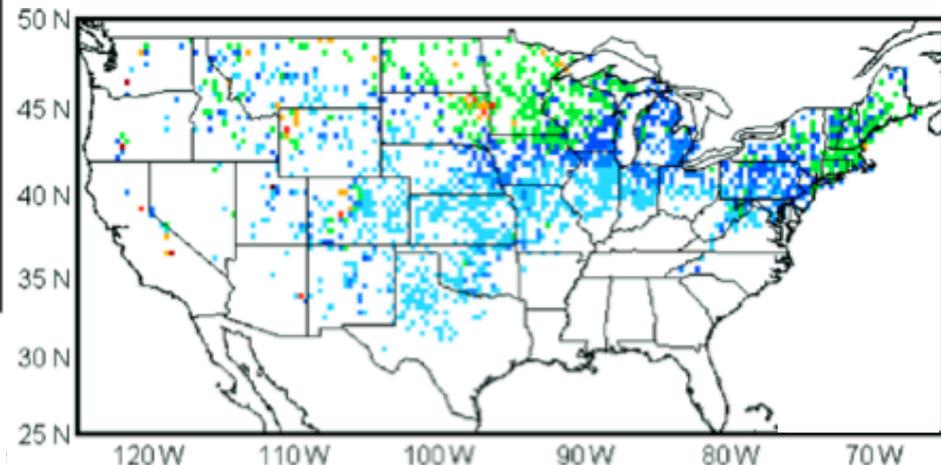
Much less RFI signals are found at 10.7h in US.

RFI Signals at 6.925 GHz Horizontal Polarization on a Snow Day over the United States: February 1, 2011

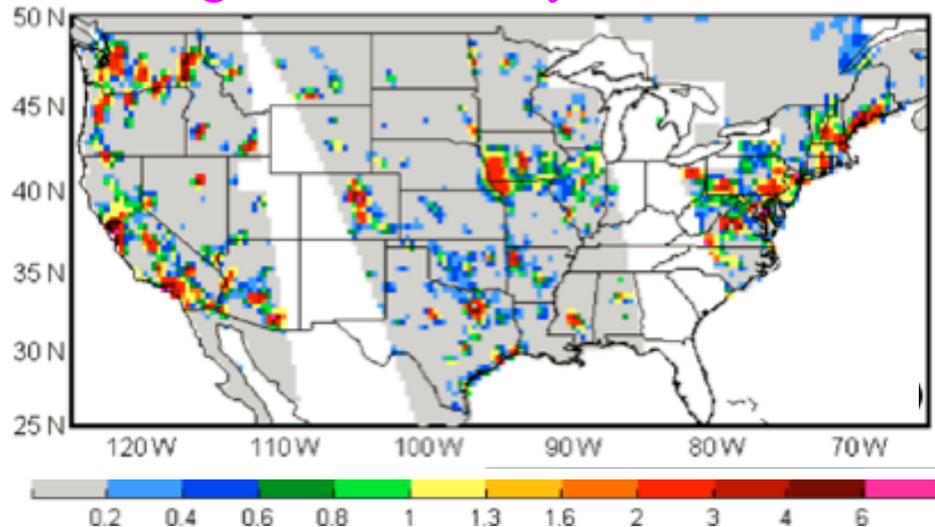
RFI signals detected by PCA method



Daily mean snow depth from NWS station observations



RFI signals detected by DPCA method



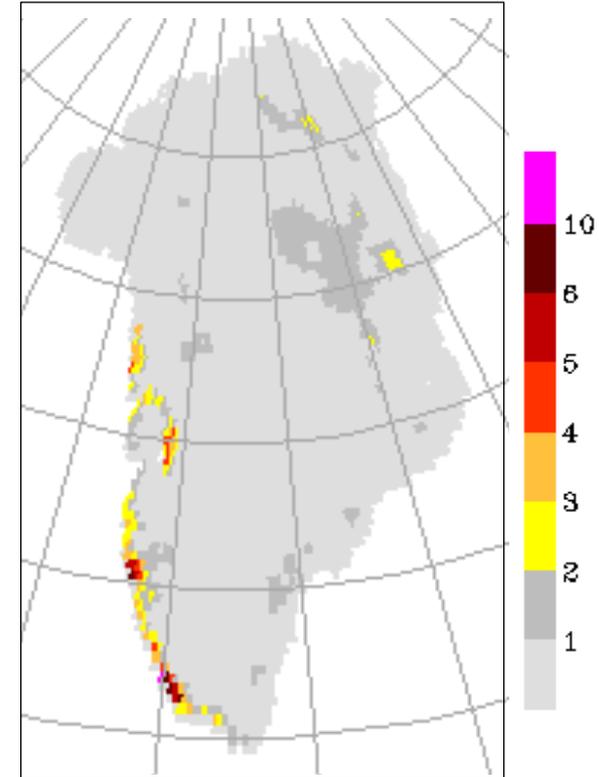
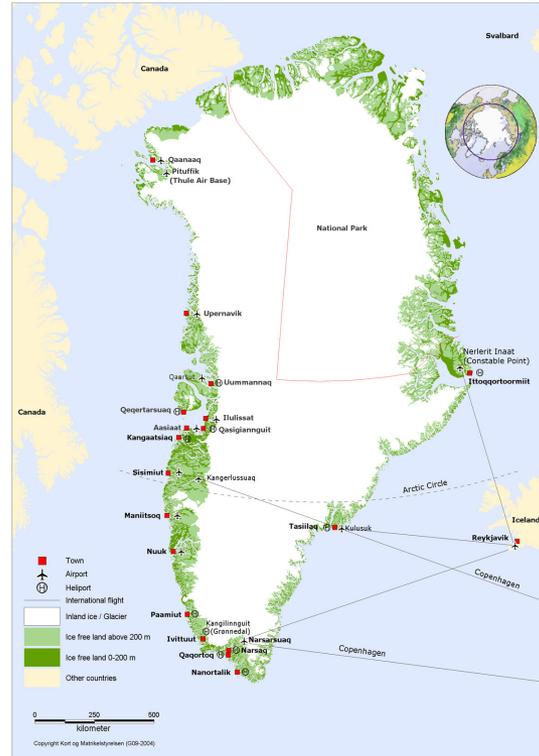
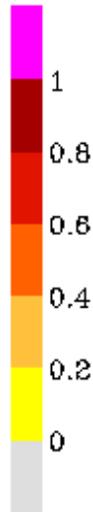
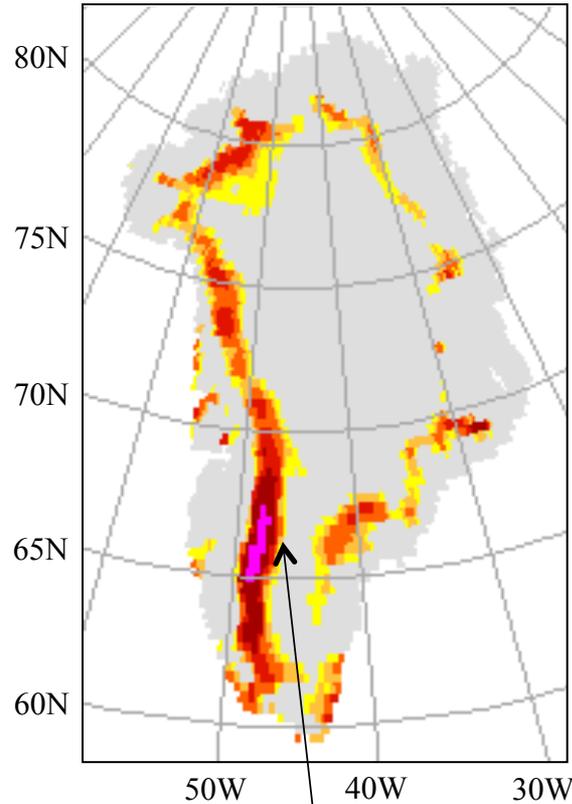
DPCA not only eliminates the false RFI signals due to snow but also detected RFI signals within snow.

RFI Detection over Greenland

RFI signals at 6.8h
detected by NPCA

Greenland
Physical Map

RFI signals at 6.8h
detected by NPCA

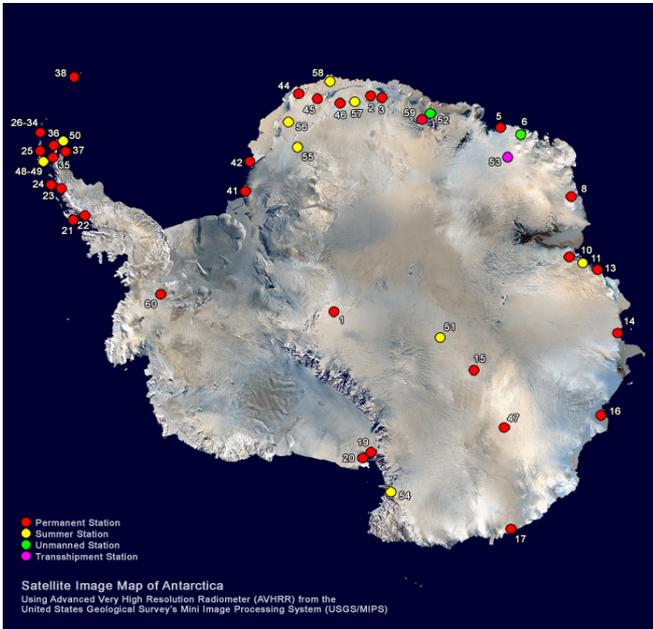


NPCA does not
Work over Greenland!

From http://www.nationsonline.org/Oneworld/map/greenland_map2.htm

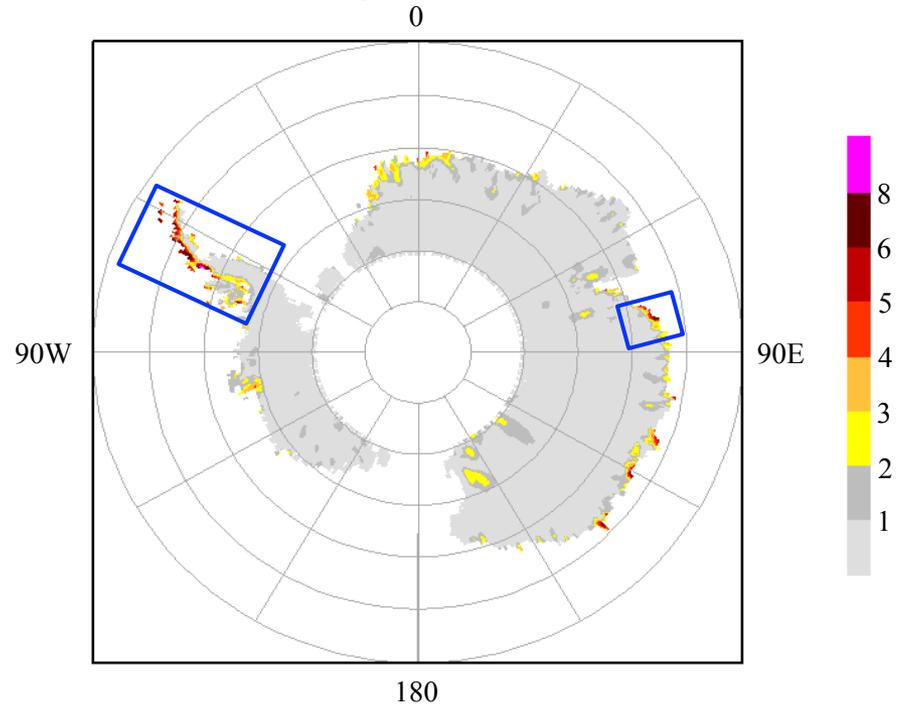
RFI Detection over Antarctic

Antarctic Research Stations



<http://www.ecophotoexplorers.com/AntarcticaStations.asp#map1>

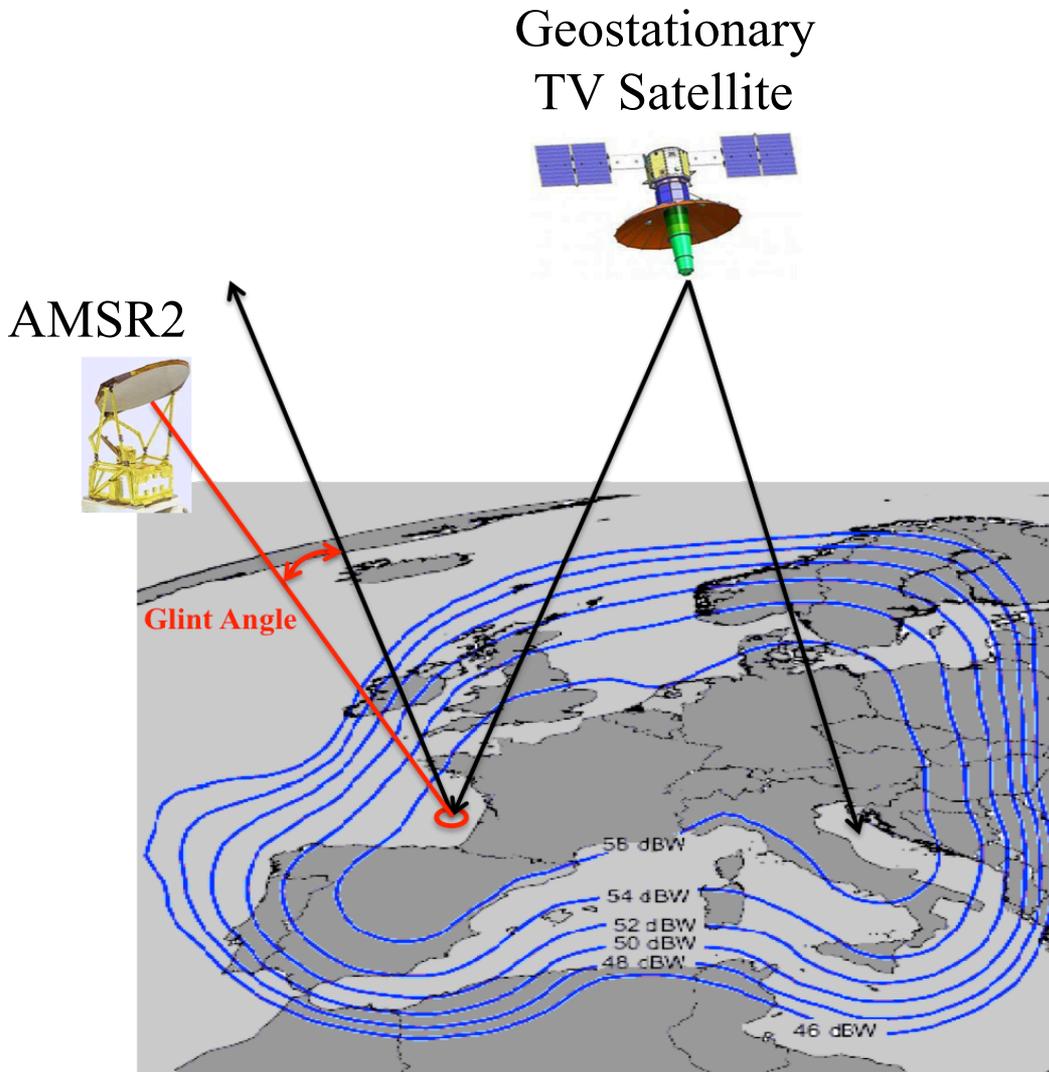
RFI Signals at 6.8h



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TFI Signal Sources over Ocean



The geostationary satellites transmit TV signals to the European Region within the bands from 10.65 to 12.75 GHz and to North America with 18.3 to 18.8 GHz.

AMSR-E is a conically scanning microwave imager on board the Aqua satellite launch into a polar orbit in May 2002.

The smaller the glint angle is, the more likely the observation is contaminated with TFI signals.

Potential Sources of TFI

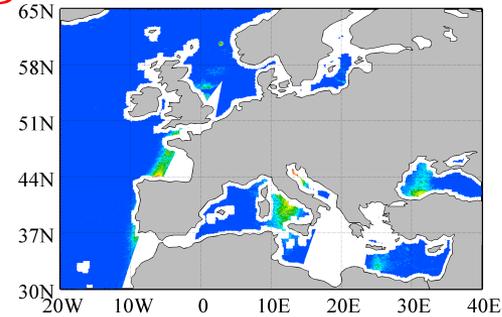
AMSR-E Channel	Satellite Name	Location	Launch Time	Area Affected
10.65 GHz	Astra	19.2 E	Apr-06	Greater Europe
	Eutelsat	10.0 E	Apr-09	
	Hotbird	13.0 E	Aug-02	
18.7 GHz	DirecTV-10	102.8 W	Jul-07	North America
	DirecTV-11	99.2 W	Mar-08	
	DirecTV-12	102.8 W	Dec-09	

The TV signals of the above satellites reflected from ocean surface have the potential to interfere with natural emission received by AMSR2 when it scans over Europe or North America.

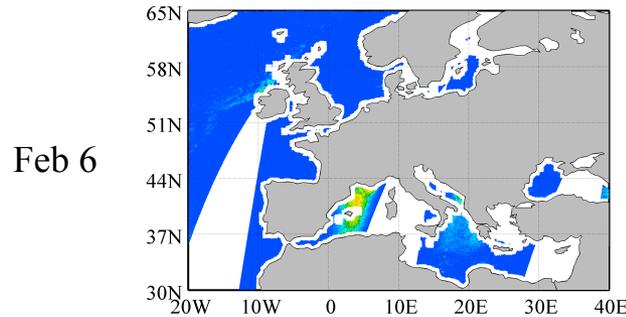
Time Variation of RFI Signals at 10.65 GHz

RFI appears near

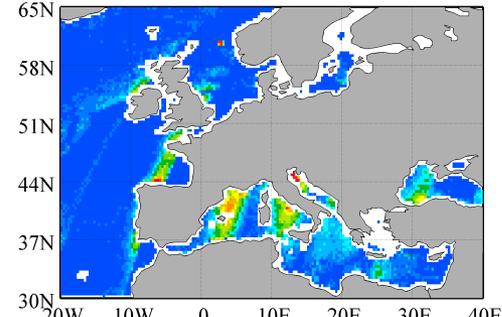
- east edges of swaths in west of Europe,
- west edges of swaths in the eastern Europe, and
- nadir for swaths right over the western Europe.



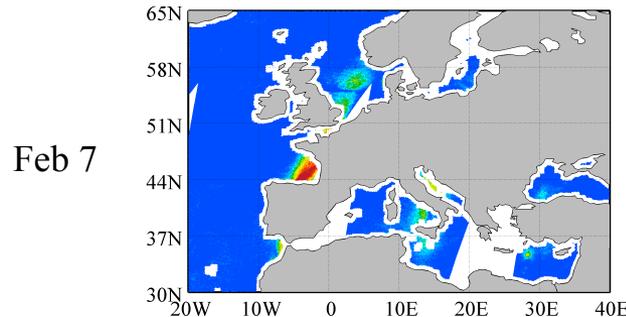
Feb 5



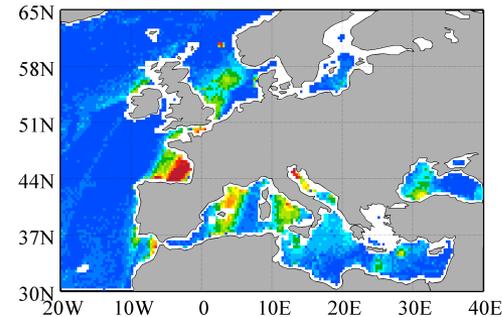
Feb 6



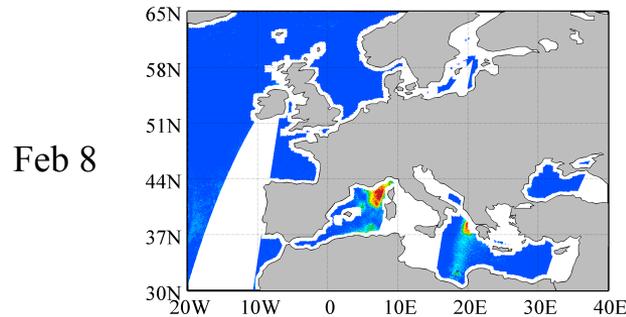
Feb 5 – Feb 6



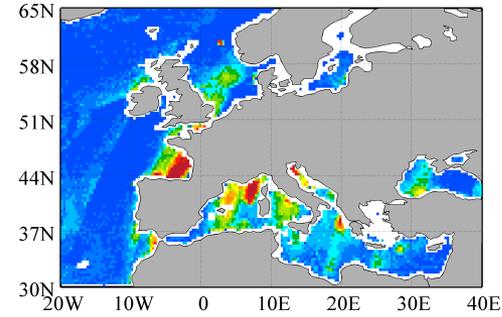
Feb 7



Feb 5 – Feb 7



Feb 8

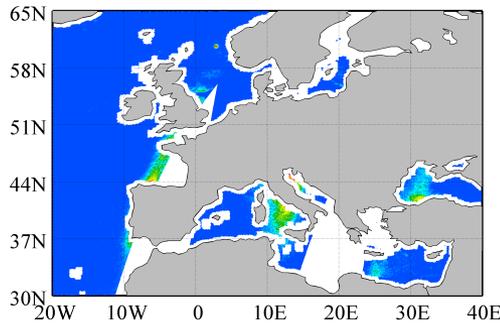


Feb 5 – Feb 8

Validation with RFI Glint Angles

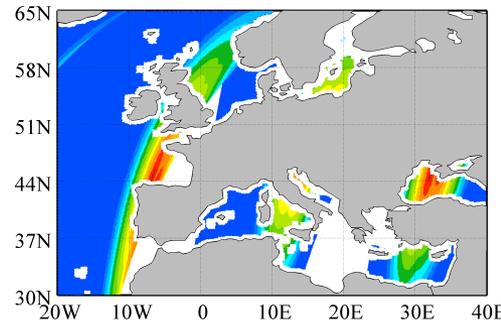
RFI at 10.65 GHz
detected by NPCA

Feb 5

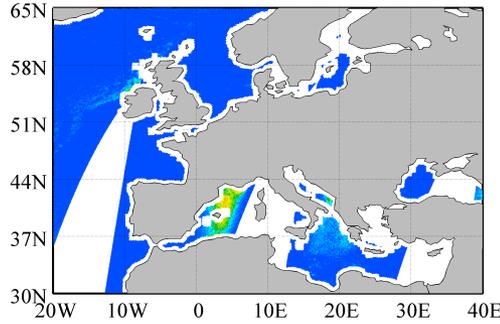


RFI Glint Angles
From AMSR-E Dataset

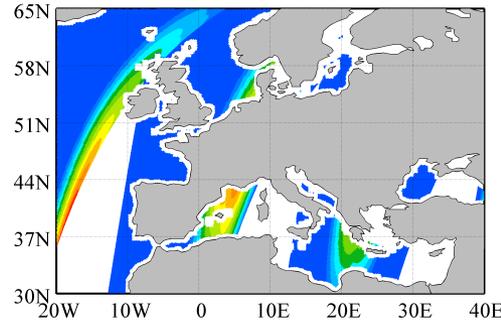
Feb 5



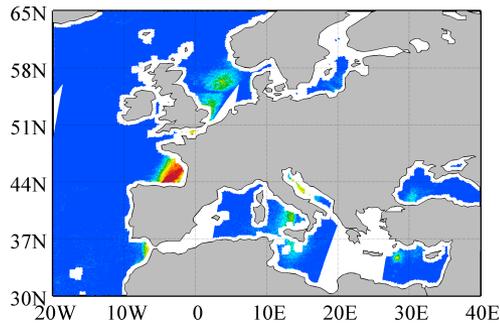
Feb 6



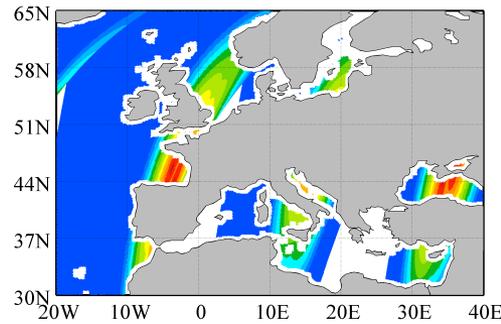
Feb 6



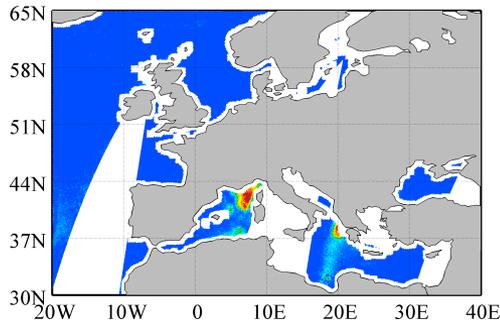
Feb 7



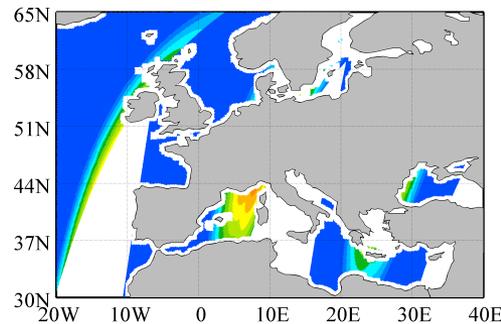
Feb 7



Feb 8



Feb 8

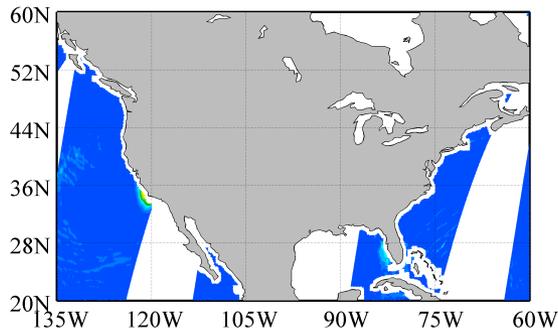


Time Variation of RFI at 18.7 GHz

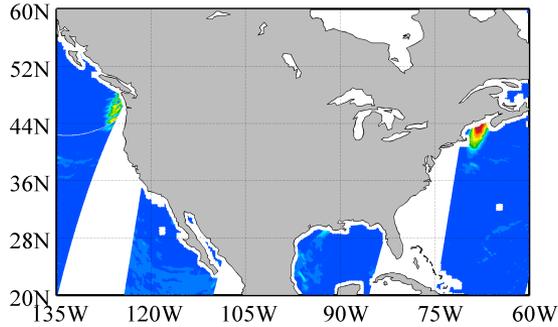
RFI at 18.7 GHz appears near

- west edges in swaths over eastern coast,
- east edges in swaths over western coast, and
- nadir when swath passes right over US.

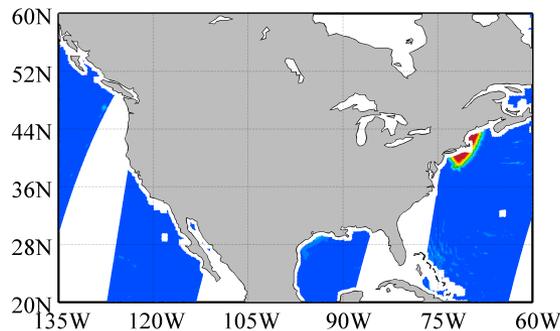
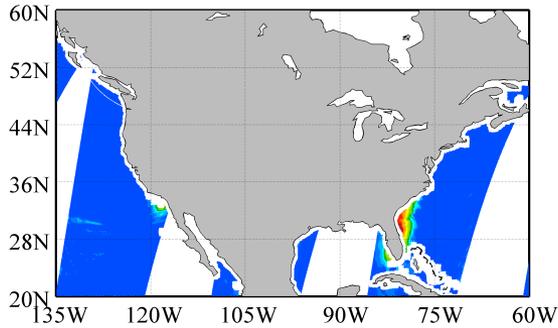
Feb 6



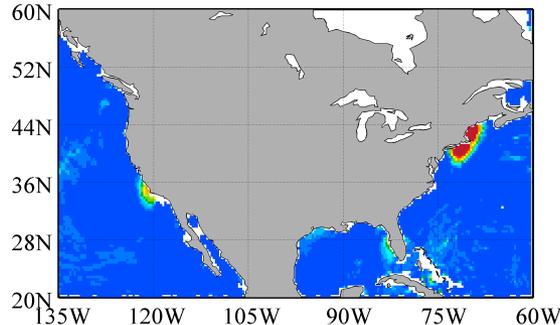
Feb 7



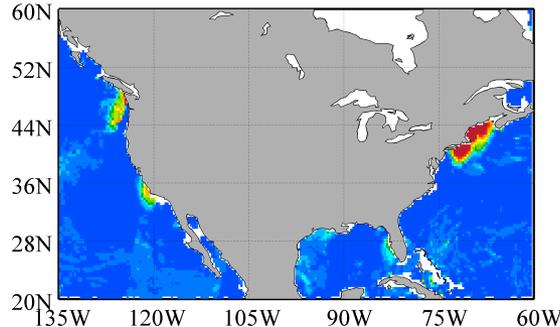
Feb 8



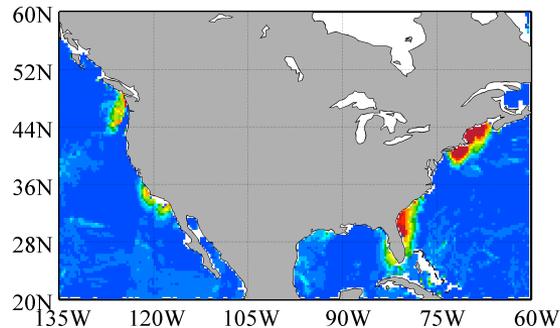
Feb 5



Feb 5 – Feb 6



Feb 5 – Feb 7

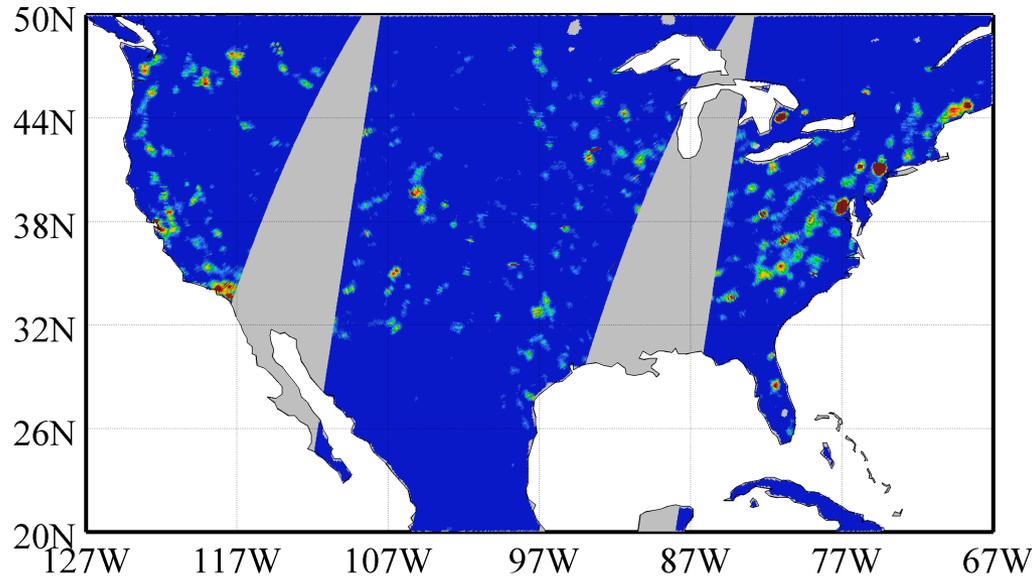


Feb 5 – Feb 8

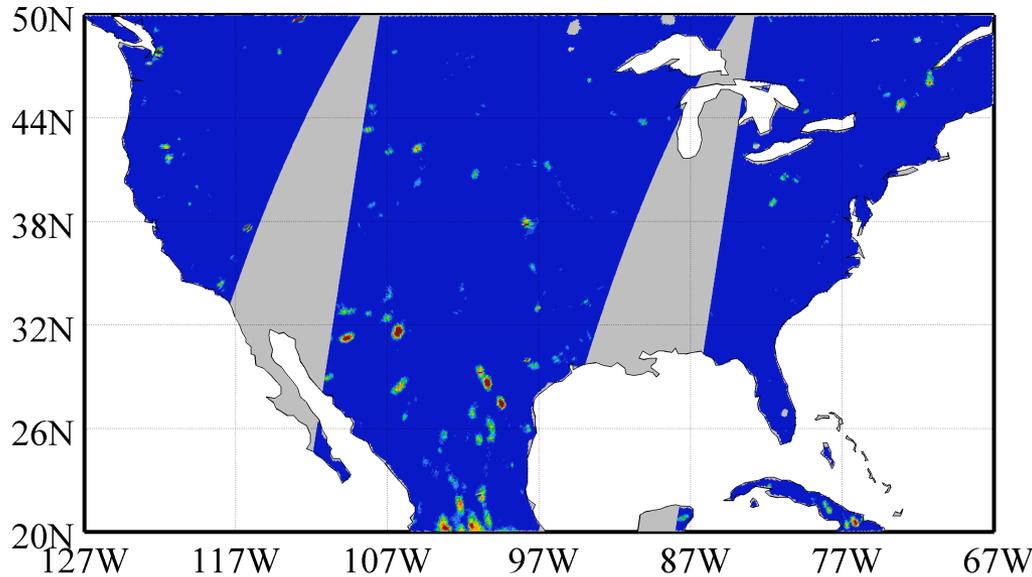
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Nearly Non-Overlapping Distributions of RFI Signals between AMSR2 6.9 and 7.3 GHz over US

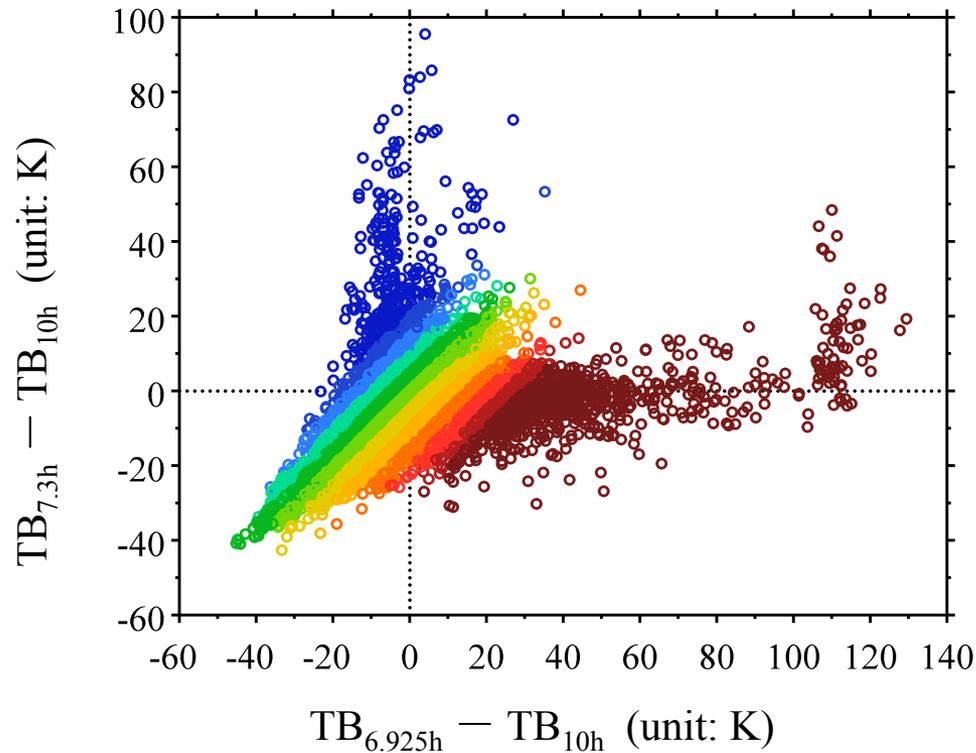


RFI signals at 6.925 GHz
(vertical polarization)



RFI signals at 7.3 GHz
(vertical polarization)

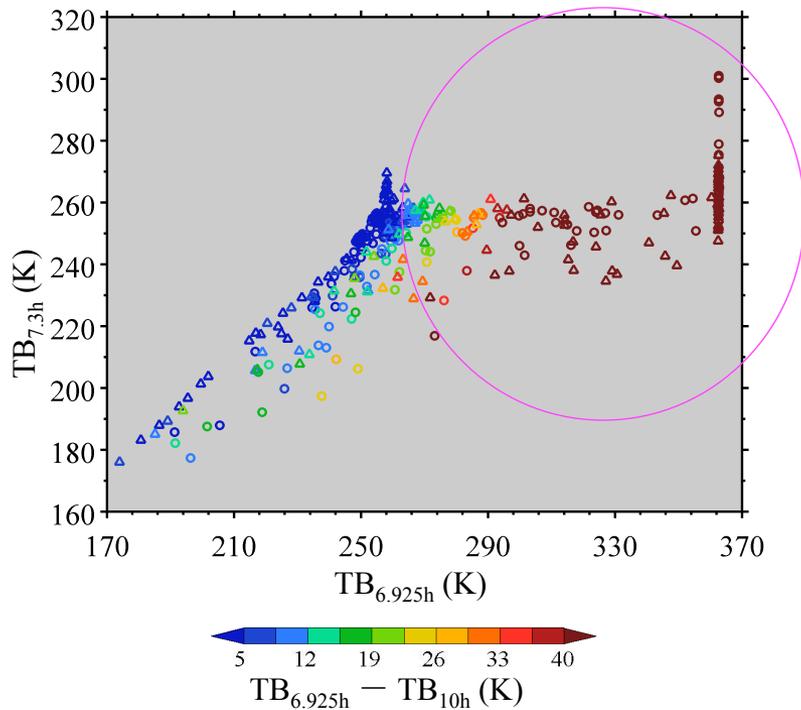
Geographically Non-Overlapping RFI Signals between 6.9 and 7.3 GHz of AMSR2 Data over US



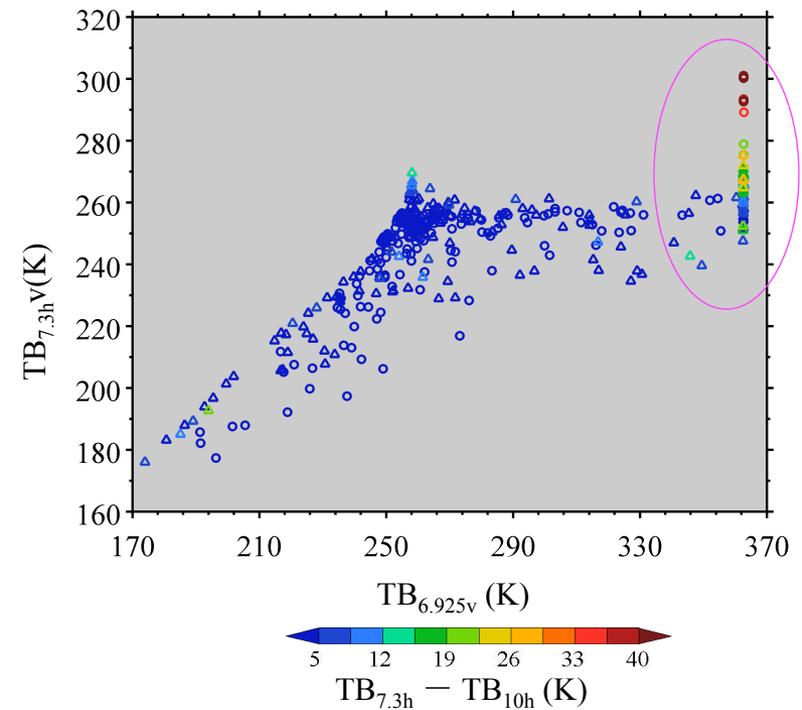
Large spectral differences at 6.925 GHz are mostly not correlated with Large spectral differences at 7.3 GHz.

AMSR2 6.925 and 7.3 GHz **Horizontally** Polarized Channels

RFI signals found at 6.925 GHz



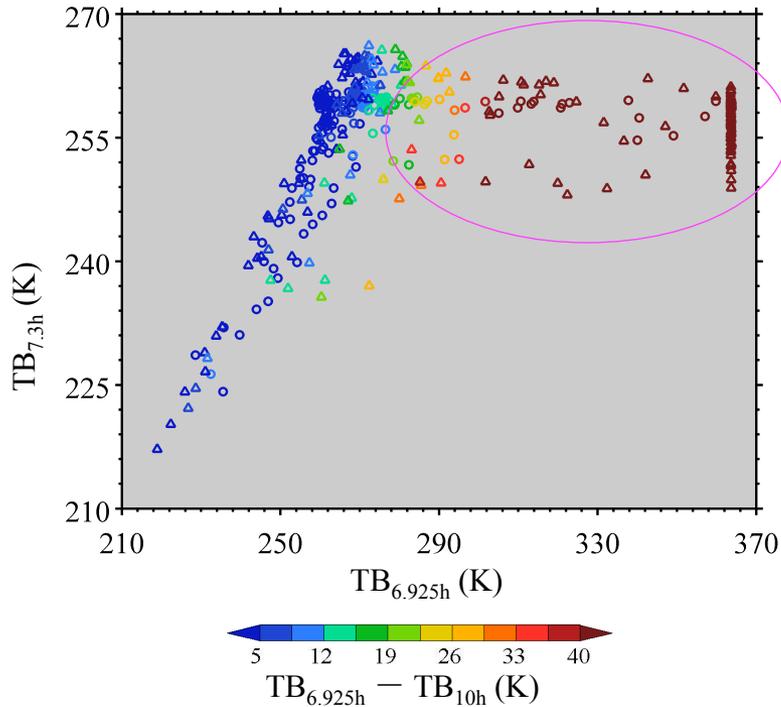
RFI signals found at 7.3 GHz



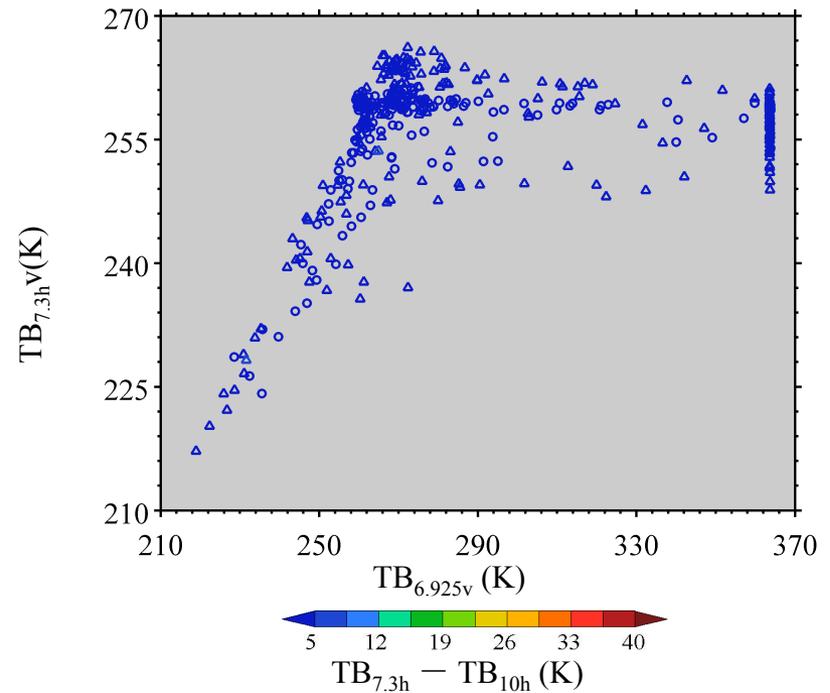
RFI signals over **Washington DC** and **New York** are detected for both 6.925 and 7.3 GHz at horizontal polarization and are characterized by higher brightness temperatures at both frequencies than those of RFI-free data.

AMSR2 6.925 and 7.3 GHz **Vertically** Polarized Channels

RFI signals found at 6.925 GHz



RFI signals not found at 7.3 GHz



For vertically polarized channels, RFI signals appear only in 6.925GHz channel over Washington D. C. and New York (left panel). The 7.3GHz vertically polarized channel is RFI-free over both Washington D. C. and New York.

Summary and Publications

RFI over land and TFI over ocean can be successfully detected anywhere over the globe using observationally-based double PCA method and normalized PCA method, respectively.

- Zou, X., J. Zhao, F. Weng and Z. Qin, 2012: Detection of **RFI signal over land** from FY-3B Microwave Radiation Imager (MWRI). *IEEE Trans. Geo. Remote Sensing*, **50**(12), 4986-4993.
- Zhao, J., X. Zou and F. Weng, 2013: Detection of **RFI signals over Greenland and Antarctic** from WinSat Microwave Radiation Imager using **a double PCA approach**. *IEEE Trans. Geo. Remote Sensing*, **51**(9), 4830-4839.
- Zou, X., X. Tian and F. Weng, 2014: Detection of **TFI** with satellite microwave imager observations over **oceans**. *J. Ocean Atmos. Tech.*, **31**, 2759–2776.
- Zou, X., F. Weng and X. Tian, 2015: An effective **mitigation of RFI** over land by adding **a new C-band on AMSR2**. *Adv. Meteor. Sci. and Tech.*, **5**(2), 45-53.
- Feng C., X. Zou and J. Zhao, 2015: Detection of **RFI signals** from AMSR-E data with **snow** over the United States. *Frontiers of Earth Sci.*, (in press)